CLAIMS

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

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A method of thermoforming, comprising:

providing a vacuum mold having an internal vacuum chamber;

heating a thermoplastic material;

drawing the heated thermoplastic material over the vacuum mold, including drawing a partial vacuum in the internal vacuum chamber; and

cooling the formed thermoplastic material by quenching the thermoplastic material while the thermoplastic material remains on the vacuum mold.

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The method of claim 1 comprising maintaining the quench at a substantially constant temperature.

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The method of claim 2 wherein the thermoplastic material is quenched in a material selected from the group consisting of water, oil, coolant and ceramic beads.

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The method of claim 3 comprising removing the thermoplastic material from the vacuum mold by reversing the vacuum and blowing a gas against the thermoplastic material.

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A thermoforming apparatus, comprising:

a vacuum mold having a surface and an internal vacuum chamber, said mold defining a plurality of vacuum holes extending between said surface and said vacuum chamber;

a quench; and

actuation means for moving said mold into said quench while a thermoplastic material is retained on said mold.

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The apparatus of claim 5 wherein said quench includes a reservoir and a quenching fluid, said reservoir being of sufficient size to receive said mold while a thermoplastic material is retained on said mold.

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The apparatus of claim 6 further comprising a temperature control means for maintaining said quenching fluid at a substantially constant temperature.

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The apparatus of claim 5 wherein said actuation means includes a carriage that supports said mold.

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The apparatus of claim 8 comprising a rack for holding at least one sheet of the thermoplastic material in a supported position.

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The apparatus of claim 9 wherein said carriage is translatable between a first position wherein said mold contacts and draws said sheet in said supported position and a second position wherein said carriage disposes said mold with said sheet retained thereon in said quench.

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The apparatus of claim 10 comprising a drive assembly that rotates said carriage along an axis so that in said first position said mold faces said sheet and so that in said second position said mold faces said quench.

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The apparatus of claim 10 wherein translation between said first and second positions requires rotation of said carriage about 180 degrees.

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The apparatus of claim 5 wherein said internal vacuum chamber is at least one of a vacuum cabinet and a network of vacuum line.

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A thermoforming system comprising:

a first station including a heater;

a second station including a vacuum mold and a quenching reservoir, said vacuum mold actuatable between a drawing position wherein said vacuum mold draws a thermoplastic sheet against said vacuum mold with a partial vacuum, and a quenching position wherein said vacuum mold is disposed in said quenching reservoir; and

a rack including a plurality of sheet-receiving openings, the rack being supportive of the thermoplastic sheet, wherein said rack moves said thermoplastic sheet to said first station and said second station.

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The thermoforming apparatus of claim 14 wherein said rack is a rotatable carousel.

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The thermoforming apparatus of claim 14 wherein said rack is disposed on a set of rails.

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The thermoforming apparatus of claim 14 wherein said vacuum mold includes a surface and an internal vacuum chamber, said vacuum mold defining a plurality of vacuum holes providing fluid communication between said internal vacuum chamber and the environment.

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A thermoforming apparatus comprising:

a cooling tank;

a mold including at least one of a vacuum cabinet and a vacuum line network in fluid communication with the environment through a plurality of vacuum holes defined by said mold; and

an actuator system supportive of said mold, said actuator system actuatable between a draw position wherein said mold draws a thermoformable sheet against said mold with a partial vacuum, and a quench position wherein said mold is disposed in said cooling tank.

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The thermoforming apparatus of claim 18 wherein said mold is of a plurality of maximum and minimum thickness regions and wherein said vacuum line network is configured in the mold adjacent to the minimum thickness regions.

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The thermoforming apparatus of claim 18 comprising a rack to hold at least one thermoplastic sheet.

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The thermoforming apparatus of claim 20 wherein said actuator system drives said mold through said rack to contact said sheet and move said sheet with said mold into said cooling tank into said quench position.

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The thermoforming apparatus of claim 18 wherein said actuator system moves said mold into said draw position and then rotates said mold a pre-selected angle so that the mold is moveable into said quench position.

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The thermoforming apparatus of claim 18 wherein said actuator system is operated by a plurality pneumatic cylinders that move said mold in a first direction to said draw position and then retract said mold away from said draw position in a second direction until said mold is disposed in said quenched position.

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The thermoforming apparatus of claim 18 wherein said thermoformable sheet is held in a rack and said actuator system drives said mold into contact with said thermoformable sheet in a first direction and then retracts said mold after the thermoformable sheet is drawn against said mold in a second direction opposite said first direction until the mold attains said quenched position.

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A method of manufacturing a thermoforming mold comprising:

forming a cavity is a mold media, the cavity corresponding in shape to the thermoforming mold;

positioning a vacuum chamber in the cavity;

supplying a molten material to the cavity to cast the mold about the vacuum chamber, the molten material conforming to the cavity and defining a mold face; and

forming at least one hole in the mold extending from the mold face to the vacuum chamber to provide communication between the vacuum chamber and the mold face.

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The method of claim 25 wherein the mold face includes a plurality of ridges and valleys, and wherein the vacuum chamber is a vacuum line network, the vacuum line network being positioned substantially coincidentally with the valleys.

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The method of claim 25 wherein the vacuum chamber and vacuum holes define the only voids in the mold.

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The method of claim 25 wherein the mold is of varying thickness and wherein the vacuum chamber is a vacuum line network, the vacuum line network extending through the mold in areas of lesser thickness.

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The method of claim 25 wherein the vacuum chamber is a vacuum line network, the vacuum line network being laid out in a grid pattern within the mold.

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A process for manufacturing a vacuum mold comprising:

impressing into a mold media a mold cavity corresponding in shape to a desired shape of the mold;

suspending a vacuum chamber in the mold cavity, the vacuum chamber having an attachment means for operatively connecting the mold cavity to a vacuum supply means;

supplying a molten material to the mold cavity, the molten material filling at least a portion of the mold cavity and surrounding at least a portion of the vacuum chamber;

curing the molten material to define the mold at least partially surrounding the vacuum chamber, the mold defining a contoured face to shape a thermoformable sheet; and

defining a plurality of holes in the mold to create fluid communication between the vacuum chamber and the face.

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The process of claim 30 wherein the vacuum chamber is a vacuum line network.

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The process of claim 30 wherein the vacuum chamber is a vacuum cabinet.